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JOHN MURRAY EXPEDITION 1933–34

SCIENTIFIC REPORTS

VOLUME III, No. 3

STRATIFICATION OF BIOLOGICAL REMAINS IN MARINE DEPOSITS

BY

H. G. STUBBINGS, M.A., PH.D.(CANTAB.), B.SC.(LOND.)

WITH FOUR TEXT-FIGURES

LONDON:
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AND AT
THE BRITISH MUSEUM (NATURAL HISTORY), CROMWELL ROAD, LONDON, S.W.7
1939

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Price Two Shillings and Sixpence

[*Issued 24th November*, 1939]

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I. INTRODUCTION.

Historical.

Instances of stratification of marine sediments were first recorded by Murray and Renard (1891), though without comment. Longer stratified cores have since been described and discussed by Murray and Philippi (1908), Philippi (1910), Murray (1912) and more recently by Wüst (1933), Wattenberg (1933) and Schott (1935). The materials for these investigations come largely from the Southern Ocean, and Central and Southern Atlantic. The main achievement of the work has been to date various strata in the cores as of glacial age. The essential link in the work was furnished by Wattenberg (1933), who showed that deposits formed beneath cold polar waters were poor in calcium carbonate owing to the unsaturation of polar water with this substance.

Recent work with a new type of apparatus (Piggot, 1936), driven into the deposit by an explosive charge, has resulted in the collection of cores up to 2·97 m. in length. Preliminary work on these (Bradley *et al.*, 1938) has shown that as many as four glacial strata are identifiable, inter-layered with Globigerina ooze or limy mud and with two layers of volcanic ash, one beneath the upper (surface) Globigerina ooze and the other between the third and fourth glacial strata. The different strata found are approximately as follows (Bradley *et al.*, 1938, pp. 42, 43):

1. Globigerina ooze.
2. Upper volcanic ash zone.
3. First glacial zone.
4. Globigerina ooze or limy clay.
5. Second glacial zone.
6. Globigerina ooze or limy clay.

7. Third glacial zone.
8. Lower volcanic ash zone.
9. Fourth glacial zone.
10. Globigerina ooze or limy clay.

The first two glacial zones may be only phases of one and the same glacial period, considered by Bradley *et al.* to correspond to the last or Wisconsin glaciation of North America. This large number of glacial strata has only been found west of the Mid-Atlantic Ridge. East of the Ridge only one glacial zone has so far been identified in the cores. The cores show great variation in the thickness of corresponding strata, indicating that the rate of deposition is very variable in different parts of the ocean.

Bradley *et al.* (1938) also summarise the work of Philippi (1910) and Schott (1935). That of Schott is of particular interest as it is on similar lines to the present work. Schott has shown that in Central Atlantic cores certain species of pelagic Foraminifera can be used to give indications of the temperature conditions at the time of deposition of the deposit. This leads to the possibility of dating a section of the core as of glacial age. Cold water species are found to be in the majority in glacial strata and warm-water species in the interglacial. Cushman (Bradley *et al.*, 1938) has found that dating of the North Atlantic cores by this means agrees with the geological interpretation.

The object of the present work is to investigate the Foraminifera of the cores obtained by the " John Murray " Expedition in an attempt to demonstrate similar " climatic " stratification of the deposits in the Arabian Sea. Only the Foraminiferal evidence is discussed here. The geological and mineralogical evidence will be discussed by co-workers on the material.

Pelagic Foraminifera.

Cushman (1933, p. 44) lists twenty-five species of wholly pelagic Foramifera and several that are pelagic for part of the life-cycle only. Schott (1935, p. 44) states that these pelagic species are for the most part stenothermic, though some are eurythermic, warm-water animals. Most species live in the warm surface waters of tropical and sub-tropical regions, where only a small annual range of temperature occurs. According to Philippi (1910, p. 568) the following species found in the Arabian Sea occur most abundantly in warm waters :

Globigerina dubia.
Globigerinoides conglobata.
Gl. rubra.
Gl. sacculifera.
Globigerinella æquilateralis.
Gl. digitata.
Orbulina universa.
Pulleniatina obliquiloculata.
Sphæroidinella dehiscens.
Globorotalia canariensis.
Gl. menardii.
Gl. truncatulinoides.
Gl. tumida.

The following three species, among others, not recorded from the present materials, are said to be most abundant in temperate waters :

Globigerina bulloides.
Gl. inflata.
Globorotalia crassa.

In the Arabian Sea the commonest species are :

Globigerina bulloides.
Gl. dubia.
Pulleniatina obliquiloculata.
Globorotalia menardii.
Gl. tumida.

Of these, only *Globigerina bulloides* and *Globorotalia menardii* are sufficiently abundant to be of general value as indicators of changing conditions. *Globorotalia tumida* is also of considerable use, as its fluctuations agree with those of *Globorotalia menardii*; but it is never sufficiently abundant to be used as a separate "indicator". Other species are of occasional use where these variations are similar to those of one or other of the above species.

MATERIALS.

Six cores from Stations 119, 127, 128, 132, 134 and 135 in the Southern Arabian Sea have been examined in detail. They lie on a line from just south-east of Zanzibar to the south end of the Maldive Archipelago.

METHODS.

In all the samples examined the procedure was the same as that already used in the investigation of the surface deposits of the Arabian Sea. A small sample of the deposit was boiled in water, with the addition of potash, if necessary, until thoroughly broken down into its component particles. The material was then washed through a linen sieve which retained the Foraminifera, while allowing the fine mud to pass through the meshes.

The samples chosen for examination are from various horizons. In each core a surface sample was examined and three or four more from various parts of the core. Where possible these samples were chosen from regions of the core that appeared to differ on superficial examination. If no variations were apparent, samples were taken at levels roughly corresponding with those on other cores. Additional samples were studied as the progress of the work required. In all 43 samples were examined as shown in Table I.

TABLE I.—*Depths in cm. Below Top of Core.*

Station.					
119.	127.	128.	132.	134.	135.
0	0	0	0	0	0
4·5	4·0	5·0	6·0	5·0	6·0
10·5	25·0	22·0	26·5	29·0	33·0
33·0	51·0	32·5	45·0	59·0	61·0
47·5	86·5	46·0	63·0	90·0	86·0
58·5	96·5	65·0	91·0	107·5	113·0
60·0	..	87·0	108·0	..	..
..	..	95·0	..	..	..
..	..	101·5	..	..	..
..	..	110·5	..	..	..
..	..	130·5	..	..	..

The Foraminifera are treated in some detail. The pelagic and many of the benthic species have been identified and are listed elsewhere (pp. 162, 183 *et seq.*). A sample of the washed material was spread out under the binocular and the numbers of each pelagic species counted. The benthic species, always represented by few individuals, were counted together. Sufficient material to include at least one thousand specimens was counted and the numbers of each species expressed as parts per thousand tests. The results of these counts are shown in Table II.

Table II.

Station.	Depth in core (cm.).	*Globigerina.*			*Globigerinoides.*			*Globigerinella.*		*Orbulina universa.*	*Pulleniatina obliquiloculata.*	*Sphæroidinella dehiscens.*	*Globorotalia.*					Benthic specimens.
		bulloides.	*dubia.*	*inflata.*	*conglobata.*	*rubra.*	*sacculifera.*	*æquilateralis.*	*digitata.*				*canariensis.*	*crassa.*	*menardii.*	*truncatulinoides.*	*tumida.*	
119	0	405	117	12	30	25	32	..	..	27	94	8	..	20	125	14	42	49
	4·5	406	123	5	33	17	33	..	..	29	99	6	..	22	129	8	47	43
	10·5	638	75	6	12	16	23	..	..	13	63	3	2	15	81	11	23	19
	33·0	796	21	1	1	97	4	..	..	5	13	..	..	..	18	..	..	44
	47·5	848	21	3	2	45	6	..	..	7	18	..	..	..	25	..	1	24
	58·5	564	111	6	22	15	20	..	..	19	66	3	5	20	91	15	18	25
	65·0	512	118	7	23	14	18	..	..	24	83	3	..	17	105	15	41	21
127	0	556	66	..	65	6	47	..	..	11	57	9	..	..	126	2	42	13
	4·0	541	51	..	60	12	38	..	..	14	53	3	..	2	173	..	49	4
	25·0	343	112	2	18	6	8	..	..	20	52	6	3	24	298	1	94	13
	51·0	643	84	..	17	..	..	..	5	14	56	19	..	18	113	7	16	8
	86·5	524	71	2	15	1	1	..	..	15	71	24	..	20	206	..	40	10
	96·5	654	57	2	3	8	8	..	..	8	43	4	2	18	167	1	20	5
128	0	496	59	10	37	1	20	..	..	10	65	15	..	17	141	7	115	7
	5·0	176	56	22	20	1	7	..	..	13	145	25	..	10	331	5	181	8
	22·0	547	67	17	32	5	52	..	1	22	71	7	1	2	147	26	..	3
	32·5	450	141	1	3	2	4	..	..	5	66	5	..	52	198	7	46	20
	46·0	281	103	8	17	3	5	2	1	11	90	11	..	78	267	39	80	4
	65·0	383	97	20	14	4	20	..	..	49	74	3	5	28	275	4	20	4
	87·0	613	57	3	2	3	2	..	..	1	40	7	1	25	186	..	51	9
	95·0	302	58	6	2	1	3	..	..	8	40	8	1	12	442	6	103	8
	101·5	207	50	9	4	..	1	..	..	4	42	12	..	22	450	2	179	18
	110·5	463	18	1	4	..	1	..	..	..	56	9	..	8	300	..	125	15
	130·5	639	100	3	5	3	3	..	..	2	23	3	..	36	162	1	10	10
132	0	707	68	31	14	..	6	..	..	1	26	2	..	..	131	..	6	8
	6·0	747	45	11	12	25	34	..	2	9	30	3	1	..	71	..	4	6
	26·5	622	78	4	12	5	12	..	1	16	69	3	1	19	142	2	10	4
	45·0	476	95	18	14	..	13	..	1	48	35	3	..	45	235	2	14	1
	63·0	613	82	10	9	6	10	..	..	9	48	6	1	20	153	12	10	11
	91·0	680	47	41	8	2	6	..	2	6	36	7	2	20	130	6	4	3
	108·0	728	49	28	9	1	11	1	2	10	40	3	1	12	96	2	3	4
134	0	479	36	2	..	..	..	..	..	3	27	46	..	..	318	..	16	73
	5·0	510	41	5	1	..	2	..	..	..	16	12	..	12	354	..	29	18
	29·0	378	46	52	12	2	2	..	..	6	68	24	..	24	350	..	24	12
	59·5	464	34	18	..	1	..	..	..	4	49	31	..	5	289	..	61	44
	90·0	288	130	82	8	..	17	21	..	16	29	37	..	..	243	..	64	65
	107·5	312	83	118	10	..	16	12	..	18	81	16	..	..	254	..	21	59
135	0	575	59	32	9	117	32	9	4	15	46	2	..	..	71	..	3	26
	6·0	528	97	43	13	39	39	14	13	22	70	2	14	..	98	..	3	5
	33·0	570	90	27	14	68	42	3	22	31	52	1	3	4	66	1	2	4
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

II. DESCRIPTION OF THE CORES EXAMINED.

In this section the origin and appearance of the cores are briefly described and the main variations in Foraminiferal content are outlined. Details of the behaviour of individual species are given in a later section (p. 168 *et seq.*) under each species.

Station 119.

Locality : South-east of Zanzibar.

Depth : 1204 m.

Length of Core : 68·5 cm.

Description : The upper 9·0 cm. is a typical pale brown Globigerina ooze. Below this, from 9·0–60·0 cm., lies a layer of very coherent mud containing far fewer specimens of pelagic Foraminifera. From 60·0 cm. to the bottom, the core is composed of Globigerina ooze very similar to that at the top of the core.

The change in Foraminiferal content in the central portion is at once seen by reference to Table II, Sta. 119 : the depths 10·5, 33·0 and 47·5 cm. lie in this layer. The corresponding figures show the numbers of each species in this zone as compared with the Globigerina ooze above and below. The numbers at 10·5 and 58·5 cm. are those in the transition layers between the mud and the Globigerina ooze. It is seen that the relative numbers of *Globigerina bulloides*, and to a lesser extent of *Globigerinoides rubra*, have increased at the expense of the other species enumerated.

The number of benthic specimens is much lower in the bottom part of the core.

There is no significant difference between the numbers of most of the pelagic species found at the surface of the deposit and at the deepest level examined—65·0 cm. It is reasonable, therefore, to assume that the Globigerina oozes at the top and bottom of this core are very similar in composition ; from which it follows that environmental conditions at the times when the top and bottom materials were deposited were similar. The probable times of deposition of these zones will be referred to later.

The following table shows those species that are more abundant and those that are rarer at 47·5 cm. (the level where *Globigerina bulloides* is most abundant) as compared with the level below.

More abundant species.	Less abundant species.
Globigerina bulloides.	*Globigerina dubia.*
Globigerinoides rubra.	*Gl. inflata.*
	Globigerinoides conglobata.
	Gl. sacculifera.
	Orbulina universa.
	Pulleniatina obliquiloculata.
	Sphæroidinella dehiscens.
	Globorotalia crassa.
	Gl. menardii.
	Gl. truncatulinoides.
	Gl. tumida.

The majority of the less abundant species are warm-water forms. *Globigerina inflata* and *Globorotalia crassa*, however, are cold-water species. *Globigerinoides rubra* is also a warm-water species, but is commoner in this zone.

Station 127.

Locality : South Somali Basin.

Depth : 4091 m.

Length of core : 96·5 cm.

Description : The core consists throughout of a brownish Globigerina ooze. There is no visible difference in the texture of the deposit at any horizon. At 57·5 cm. there is a slight change in colour to a greyish brown.

There is a significant drop in the numbers of *Globigerina bulloides* at 25·0 cm. (Table II), with a corresponding rise in numbers of the warm-water forms *Globorotalia menardii* and *Gl. tumida*. Somewhat lower, at 51·0 cm., there is a big rise in the numbers of *Globigerina bulloides*, probably to be correlated with the colour change at 57·5 cm., with a considerable fall in numbers of both *Globorotalia menardii* and *Gl. tumida*. Lower still, at 86·5 cm., the number of *Globigerina bulloides* is very near that in the two top samples. The numbers of *Globorotalia tumida* also are approximately equal at the surface and in this sample. At 96·5 cm. the number of *Globigerina bulloides* is still higher and many of the other species are less abundant than at 86·5 cm.

The following species show significant differences in abundance at the depths indicated as compared with the numbers in the sample next below :

	More abundant species.	Less abundant species.
4·0 cm.	*Globigerina bulloides.*	*Globigerina dubia.*
	Globigerinoides conglobata.	*Orbulina universa.*
	Gl. rubra.	*Sphæroidinella dehiscens.*
	Gl. sacculifera.	*Globorotalia crassa.*
		Gl. menardii.
		Gl. tumida.

Thus the commonest cold-water species, *Globigerina bulloides*, shows an increase, while *Globorotalia crassa*, also a cold-water form, shows a decrease in numbers. Similarly, while most warm-water species show a decrease in numbers, the three species of *Globigerinoides* show an increase.

25·0 cm.	*Globigerina dubia.*	*Globigerina bulloides.*
	Globigerinoides rubra.	*Sphæroidinella dehiscens.*
	Gl. sacculifera.	
	Orbulina universa	
	Globorotalia crassa.	
	Gl. menardii.	
	Gl. tumida.	

Several other species show slight changes in numbers at this level. Of the above, more abundant species, only one, *Globorotalia crassa*, is a cold-water form.

51·0 cm.	*Globigerina bulloides.*	*Pulleniatina obliquiloculata.*
	Gl. dubia.	*Sphæroidinella dehiscens.*
		Globorotalia menardii.
		Gl. tumida.

In addition, *Globigerinoides conglobata* shows a slight increase and *Globorotalia crassa* a slight decrease in numbers.

86·5 cm.	*Globigerina dubia.*	*Globigerina bulloides.*
	Globigerinoides conglobata.	*Globigerinoides rubra*
	Orbulina universa.	*Gl. sacculifera.*
	Pulleniatina obliquiloculata.	
	Sphæroidinella dehiscens.	
	Globorotalia menardii.	
	Gl. tumida.	

Thus several species said to be warm-water forms fluctuate with *Globigerina bulloides* at this station, while *Globorotalia crassa*, a cold-water form, agrees with the warm-water species in the top 4·0 cm. of the core.

There is thus an alternate rise and fall in the numbers of most species at this station. Furthermore, the species with some exceptions fall into two groups. One group shows an increase in numbers while the other shows a decrease at the same horizon. At alternate horizons the other group shows an increase.

The species thus show three fluctuations as against the one in the core from Sta. 119. Similar fluctuations, though not always three in number, occur in all the following cores.

Station 128.

Locality : South Somali Basin.

Depth : 4060 m.

Length of core : 132·0 cm.

Description : A transitional ooze throughout, similar to that from Sta. 127 but containing more red clay.

Large numbers of *Globigerina bulloides* occur at 0, 22·0, 87·0 and 130·5 cm. Small numbers of *Pulleniatina obliquiloculata*, *Globorotalia menardii* and *Gl. tumida* correspond to each of these. The commoner species exhibit four maxima (*Gl. bulloides*) or minima (*Globorotalia menardii*).

The following species are more or less abundant at the levels where *Globigerina bulloides* is present in large numbers, as compared with the sample next below :

	More abundant species.	Less abundant species.
0 cm.	*Globigerina bulloides.*	*Globigerina inflata.*
	Gl. dubia.	*Orbulina universa.*
	Globigerinoides conglobata.	*Pulleniatina obliquiloculata.*
	Gl. sacculifera.	*Sphæroidinella dehiscens.*
	Globorotalia crassa.	*Globorotalia menardii.*
	Gl. truncatulinoides.	*Gl. tumida.*
22·0 cm.	*Globigerina bulloides.*	*Globigerina dubia.*
	Gl. inflata.	*Globorotalia crassa.*
	Globigerinoides conglobata.	*Gl. menardii.*
	Gl. rubra.	*Gl. tumida.*
	Gl. sacculifera.	
	Orbulina universa.	
	Pulleniatina obliquiloculata.	
	Sphæroidinella dehiscens.	
	Globorotalia truncatulinoides.	

	More abundant species.	Less abundant species.
87·0 cm.	*Globigerina bulloides.*	*Globigerina inflata.*
	Globigerinoides rubra.	*Globigerinoides conglobata.*
	Globorotalia crassa.	*Gl. sacculifera.*
		Orbulina universa.
		Sphæroidinella dehiscens.
		Globorotalia menardii
		Gl. truncatulinoides.
		Gl. tumida.
130·5 cm.	*Globigerina bulloides.*	*Pulleniatina obliquiloculata.*
	Gl. dubia.	*Sphæroidinella dehiscens.*
	Gl. inflata.	*Globorotalia menardii.*
	Globigerinoides conglobata.	*Gl. tumida.*
	Gl. rubra.	
	Gl. sacculifera.	
	Globorotalia crassa.	

Comparing these four levels, it is seen that certain species fluctuate in the same direction fairly constantly. Thus *Globigerina bulloides*, *Gl. dubia*, *Globigerinoides conglobata*, *Gl. sacculifera* and *Globorotalia crassa* tend to increase together. At the same levels *Globigerina inflata*, *Orbulina universa*, *Pulleniatina obliquiloculata*, *Sphæroidinella dehiscens*, *Globorotalia menardii* and *Gl. tumida* usually fall in numbers. At 22·0 cm. *O. universa*, *P. obliquiloculata* and *Sph. dehiscens* actually increase, but in the case of the latter two the increase is very small. The remaining species, the numbers of which are often small, do not follow either of the species, *Globigerina bulloides* and *Globorotalia menardii*.

In the intervening samples from this core the set of species containing *Gl. menardii* increases, while the numbers of the other set decrease.

Station 132.

Locality : On the Carlsberg Ridge.

Depth : 4082 m.

Length of core : 116·0 cm.

Description : An almost pure, pale cream Globigerina ooze. The portion from 70·0 cm. to the bottom is greyish in colour.

There is a very distinct maximum concentration of *Globigerina bulloides* at 6·0 cm. (Table II) and again at 108·0 cm., in both cases coincident with low numbers of *Globorotalia menardii*. *Globigerina bulloides* is least common at 45·0 cm. where *Globorotalia menardii* exhibits a maximum. The species showing an increase or decrease in numbers at 6·0 cm. and 45·0 cm. are shown below. Most of those showing a decrease at 6·0 cm. show an increase at 45·0 cm.

	More abundant species.	Less abundant species.
6·0 cm.	*Globigerina bulloides.*	*Globigerina dubia.*
	Gl. inflata.	*Orbulina universa.*
	Globigerinoides rubra.	*Pulleniatina obliquiloculata.*
	Gl. sacculifera.	*Globorotalia crassa.*
		Gl. menardii.
		Gl. tumida.
		Gl. truncatulinoides.

	More abundant species.	Less abundant species.
45·0 cm.	*Globigerina dubia.*	*Globigerina bulloides.*
	Gl. inflata.	*Globigerinoides rubra.*
	Globigerinoides conglobata.	*Pulleniatina obliquiloculata.*
	Gl. sacculifera.	*Sphæroidinella dehiscens.*
	Orbulina universa.	*Globorotalia truncatulinoides.*
	Globorotalia menardii.	
	Gl. crassa	
	Gl. tumida.	

Station 134.

Locality : South end of the Arabian Basin, west of the Maldive Archipelago.

Depth : 4234 m.

Length of core : 118·0 cm.

Description : Globigerina ooze throughout.

There are slightly larger numbers of *Globigerina bulloides* in this core at 5·0 cm., corresponding to the maximum of this species at 6·0 cm. in the preceeding core This increase is not, however, reflected by a low concentration of *Globorotalia menardii*, which is most abundant at this level. *Pulleniatina obliquiloculata* is rather scarce here. Small numbers of *Gl. bulloides* were found at 90·0 cm., corresponding to slightly increased numbers of *Globorotalia tumida*, but not of *Gl. menardii*. Both *Globigerina bulloides* and *Globorotalia menardii* are more abundant again at 107·5 cm., but *Gl. tumida* is less frequent.

It is remarkable that at this station *Globigerina bulloides* and *Globorotalia menardii* increase at the same horizons, whereas at the other stations they almost always fluctuate in opposite directions. The fluctuations of other species are also irregular.

Station 135.

Locality : West of the Maldives, on the edge of the Arabian Basin.

Depth : 2727 m.

Length of core : 120·5 cm.

Description : Globigerina ooze throughout. The upper 28·5 cm. are fawn-coloured. Below this level the deposit has a greyish tint, which is more pronounced from 86·0 cm. to the bottom of the core.

Large numbers of *Globigerina bulloides* occur at 0 and 33·0 cm. along with small numbers of other species (see Table II). Below the latter level the numbers of *Globigerina bulloides* decrease fairly steadily, while those of *Pulleniatina obliquiloculata* and *Globorotalia menardii* increase. The species differing in abundance at 0 and 33·0 cm. are shown below.

	More abundant species.	Less abundant species.
0 cm.	*Globigerina bulloides.*	*Globigerina dubia.*
	Globigerinoides rubra.	*Gl. inflata.*
		Globigerinoides conglobata.
		Gl. sacculifera.
		Orbulina universa.
		Pulleniatina obliquiloculata.
		Globorotalia menardii.

	More abundant species.	Less abundant species.
33·0 cm.	*Globigerina bulloides.*	*Globigerina dubia.*
	Globigerina conglobata.	*Gl. inflata.*
	Gl. sacculifera.	*Globigerinoides rubra.*
	Orbulina universa.	*Globorotalia menardii.*
	Pulleniatina obliquiloculata.	*Gl. tumida.*

In the above lists the less common species have been omitted.

Orbulina universa and *Pulleniatina obliquiloculata* behave irregularly at this station. At the surface they agree with the warm-water species, *Globorotalia menardii*, in being less common, but at 33·0 cm. they are present in increased numbers, though here the warm-water species are again less common.

As already remarked (p. 165), it is apparent from the foregoing lists that a number of species tend usually to fluctuate in the same direction. Thus the following six species frequently show an increase or decrease in numbers at the same level :

Globigerina inflata.	*Sphæroidinella dehiscens.*
Orbulina universa.	*Globorotalia menardii.*
Pulleniatina obliquiloculata.	*Gl. tumida.*

Of this group, *Gl. menardii* is the most abundant.

Globigerina bulloides almost always shows an opposite fluctuation to the above species. No other species varies in this manner so constantly, but the following frequently fluctuate with *Gl. bulloides*, though occasionally they may agree with the above group of species :

Globigerina dubia.	*Globigerinoides sacculifera.*
Globigerinoides conglobata.	*Globorotalia crassa.*
Gl. rubra.	

The remaining four species, *Globigerinella æquilateralis*, *Gl. digitata*, *Globorotalia canariensis* and *Gl. truncatulinoides*, are rarer or do not show any marked tendency to agree with either *Globigerina bulloides* or *Globorotalia menardii*.

III. THE PELAGIC FORAMINIFERA.

The same pelagic species occur constantly in almost all the samples examined from the six cores. The sixteen species represented will be treated individually below, and an account of the fluctuations, which I have briefly outlined in the previous section, will be amplified under each species.

Globigerina bulloides d'Orbigny.

This is a cold-water species. Tests are always present and for the most part fragmentary. The following figures show the number likely to be present in a 1000 tests of all kinds from the deposit :

Range of numbers 176–848 per 1000.[1]

Mean 530.

Distribution : There appears to be no correlation of this species with depth or distance

[1] The " range of numbers " gives the largest and smallest numbers of the species found in all the samples from all the cores. The " mean " is the average of all these samples.

from land. It appears to be fairly evenly distributed over the whole Arabian Sea in the deposits. The following means were found for the six stations :—

Station	119	127	128	132	134	135
Mean	596	544	414	653	405	497[1]

Reference to Table II shows that the number of examples of this species that are present frequently shows violent fluctuations. The fluctuations at each station are as follows :

Sta. 119 : The two top samples and the lowest contain similar numbers. (This is also the case for other species in this core.) The intermediate portion contains many more *Globigerina bulloides*. This is the mud portion of the core ; the other samples are from Globigerina ooze.

Sta. 127 : There are very large numbers of *Globigerina bulloides* at about 51·0. cm. ; a little higher up at 25·0 cm. the number is almost halved. Higher still, in the top two samples, the number is high again and approximates to that found at 86·5 cm. At 96·5 cm. the number of *Gl. bulloides* is higher than at 51·0 cm. The surface maximum apparently corresponds to that at Sta. 119. The other two maxima are not represented at that station.

Sta. 128 : As already mentioned, the number of specimens fluctuates considerably from level to level. Large numbers occur at 0, 22·0, 87·0 and 130·5 cm. There is a very big drop in numbers at 5·0 cm. and smaller ones between the above levels.

Sta. 132 : There is a steady fall to the middle of this core and then a rise to the bottom. Large numbers occur at 6·0 and 108·0 cm.

Sta. 134 : Fluctuations are small at this station. Large numbers occur at 5·0 cm. and there are other slight increases in numbers at 59·5 and 107·5 cm. Smaller numbers occur in the intermediate levels, especially at 90·0 cm.

Sta. 135 : Large numbers occur at 0 and 33·0 cm. with a small drop in between at 6·0 cm. Numbers are considerably less in the lower levels, with a decided minimum at 113·0 cm.

Globigerina dubia Egger.

This species inhabits warmer waters than the preceding, and is probably most abundant in temperate-subtropical regions. It is fairly common in all samples examined. The tests are usually intact. The following are the numbers of specimens found :

Range of numbers 21–141 per 1000.
Mean 75.

Distribution : There appears to be some correlation between the number of tests present and the depth. The species is also rather more abundant in deposits from the western side of the Arabian Sea, though it occurs commonly throughout the area. The figures below illustrate this correlation (the stations are in order from west to east) :

Station	119	127	128	132	134	135
Mean	84	74	73	66	62	93
Depth (m.)	1204	4091	4060	4082	4234	2727

Sta. 119 : The numbers at the top and bottom of the core are similar, as in the case of

[1] These means are an average of the samples from all the levels at the respective stations.

the preceding species. Very few in comparison occur in the levels (33·0 and 47·5 cm.) in which *Globigerina bulloides* is so abundant. The same phenomenon is seen in all the following species, with the exception of *Globigerinoides rubra*, and need not be reiterated under each one.

Sta. 127 : The maximum number occurs with the minimum of *Globigerina bulloides* at 25·0 cm. At other levels above and below this horizon the numbers are considerably less.

Sta. 128 : The maximum number of tests is found just below the level of the second *Globigerina bulloides* maximum (22·0 cm.) at 32·5 cm. A second large number occurs with many *Gl. bulloides* at 130·5 cm., but the intermediate *Gl. bulloides* maximum at 87·0 cm. is not represented.

Sta. 132 : Low numbers correspond to the upper *Gl. bulloides* maximum. There is a maximum concentration at 45·0 cm. Below this level the number of specimens falls off.

Sta. 134 : Numbers are relatively uniform in the upper half of the core. There is a very definite maximum at 90·0 cm. where *Globigerina bulloides* is less frequent.

Sta. 135 : The species varies inversely as *Globigerina bulloides* at all horizons.

Thus *Globigerina dubia* appears as a rule to vary inversely as *Gl. bulloides*, but it appears to fluctuate irregularly at Sta. 128. This inconsistency renders it unreliable as a guide to climatic conditions.

Globigerina inflata d'Orbigny.

Globigerina inflata is a cold-water form. It is present at all six stations in small numbers, but is absent from three of the horizons examined at Sta. 127. The tests are usually intact.

Range of numbers 0–118 per 1000.
Mean 19.

The numbers of this species are very much higher at the three eastern stations. There is no apparent depth correlation. Mean numbers for each station follow :

Station	119	127	128	132	134	135
Mean	6	1	9	21	46	41

Sta. 119 : Although this is a cold-water form there is no maximum at this station corresponding to that of *Globigerina bulloides*. On the contrary, only one test in a thousand at this horizon belongs to this species. A possible explanation of this apparent anomaly may be that both species occupy the same habitat, and are in competition and the more abundant *Globigerina bulloides* ousts the other.

Sta. 127 : The species is very rare.

Sta. 128 : The numbers fluctuate in the opposite direction to those of *Globigerina bulloides*, except between 22·0 and 32·5 cm., where both decrease in numbers. There are considerably more specimens in the upper 22·0 cm. than at any lower level except at 65·0 cm.

Sta. 132 : Increased numbers lie at different levels to those of *Globigerina bulloides*. There is a distinct minimum at 26·5 cm., above that of the latter species. The numbers rise at 45·0 cm., where *Globigerina bulloides* is scarcest, fall somewhat at 63·0 cm., and rise again at 91·0 cm. to fall again at 108·0 cm., where *Gl. bulloides* increases in numbers again.

Sta. 134 : The upper 5·0 cm. are poor in *Globigerina inflata*. Greater numbers occur at 29·0 and 90·0 cm. At 107·5 cm. there is a further increase in numbers, though *Globigerina bulloides* also increases at this level.

Sta. 135 : *Globigerina inflata* is quite common at all levels in this core. Fluctuations alternate with those of *Gl. bulloides* down to 61·0 cm. At 86·0 cm. this species and *Gl. bulloides* are both more common than at the level above (61·0 cm.), but at 113·0 cm. *Gl. bulloides* decreases in numbers, while *Gl. inflata* rises to its maximum.

Globigerinoides conglobata (Brady).

This species is present in all but two of the samples examined. It is never very common, though quite frequent at Sta. 127. According to Philippi (1910, p. 568) it is a warm-water species.

Range of numbers 0–65 per 1000.
Mean 15.

Gl. conglobata appears to be rather commoner on the west side of the Arabian Sea. The following are average numbers per sample at each station :

Station	119	127	128	132	134	135
Mean	18	27	13	11	5	12

Sta. 119 : In the mud zone (33·0–47·5 cm.) this species is extremely rare, but it is fairly common in the two Globigerina ooze zones (0–10·5 cm. and 58·5–65·0 cm.). Rather fewer specimens occur in the lower Globigerina ooze as compared with the upper.

Sta. 127 : The number of specimens in the upper 4·5 cm. is considerably higher than elsewhere in the core. It falls steadily from the top to near the bottom of the core and then sharply at the bottom. There is no fluctuation in numbers corresponding to the increase in numbers of *Globigerina bulloides* at 51·0 cm.

Sta. 128 : Numbers are high in the upper 22·0 cm. There is a marked fall at 32·5 cm. followed by a rise at 46·0 cm. and a second fall at 87·0 cm. From this point to the bottom of the core *Gl. conglobata* is uncommon. These variations correspond to opposite fluctuations of *Globigerina bulloides*.

Sta. 132 : There is little change in numbers in the top 45·0 cm. At 63·0 cm. the number falls slightly and remains constant from this level to the bottom of the core.

Sta. 134 : *Globigerinoides conglobata* is absent from two horizons. Those in which it is fairly common (29·0 and 107·5 cm.) are those in which *Globigerina bulloides* is less common.

Sta. 135 : The species is uniformly abundant throughout the core.

Globigerinoides rubra (d'Orbigny).

This species is present at all stations though absent from some samples. It is generally rare, but rather common at all levels at Sta. 135. It is said to occur mainly in warm waters.

Range of numbers 0–119 per 1000.
Mean 18.

The tests of this species seem to survive best in shallow water. Being very small, they are presumably easily broken and dissolved. The means at each station follows :

Station	119	127	128	132	134	135
Mean	33	6	2	6	1	75

Sta. 119 : It is fairly common throughout the core, especially at 33·0 cm. Of all the pelagic species this and *Globigerina bulloides* are the only ones to be more abundant at this level than elsewhere.

Sta. 127 : It is present in the upper half of the core, but practically absent below. A maximum occurs at 4·0 cm., but there is no apparent correlation with the fluctuations of *Globigerina bulloides*.

Sta. 128 : A few specimens occur at each level except 101·5 and 110·5 cm.

Sta. 132 : There is a maximum at 6·0 cm. corresponding to one of *Globigerina bulloides*. Below this level few specimens occur.

Sta. 134 : The species is almost absent.

Sta. 135 : There is a maximum at the surface (cf. *Globigerina bulloides*), and another at 61·0 cm., somewhat lower than that of *Gl. bulloides*. There is a considerable drop in numbers at 86·0 cm. and a slight rise at 113·0 cm.

Globigerinoides sacculifera (Brady).

This warm-water species is present in most of the samples examined. The range in number of specimens is smaller than for *Globigerinoides rubra*.

Range of numbers 0–52 per 1000.
Mean 15.

It appears to be fairly evenly distributed in the deposits, with a slight tendency to be commoner in the lesser depths.

Station	119	127	128	132	134	135
Mean	19	17	11	13	6	30

Sta. 119 : This species shows the fall in numbers at 33·0 cm. already seen in the foregoing species with the exception of *Globigerinoides rubra*. The number increases again in the lower layer of Globigerina ooze, but is slightly less than in the upper layer.

Sta. 127 : Considerable numbers occur in the upper 4·0 cm., but there is a big drop at a depth of 25·0 cm. Lower in the core the species is practically absent, but it is a little more frequent at the very bottom of the core.

Sta. 128 : *Gl. sacculifera* is fairly common at the surface, but in the first 5·0 cm. the number drops to a third of its surface value. At 22·0 cm. it rises considerably to fall again at 32·5 cm., and to rise again at 65·0 cm. The species is rare from 87·0 cm. to the bottom of the core.

Sta. 132 : The maximum number is found at 6·0 cm. This is in agreement with *Globigerina bulloides* and *Globigerinoides rubra* at this station. At 26·5 cm. and lower the number is much less and reaches a minimum at 91·0 cm., equal to the number at the surface.

Sta. 134 : The distribution is the reverse of that at Sta. 127. There are very few specimens in the first 60·0 cm., but from 90·0 cm. to the bottom the number is greater.

Sta. 135 : *Globigerinoides sacculifera* is common here. The largest numbers occur at 33·0 cm. Below this level the numbers are only about half those in the upper half of the core. In this half slightly more specimens occur at 86·0 cm. There is a further slight fall in numbers at 113·0 cm. at the bottom of the core.

Globigerinella æquilateralis (Brady).

This is a warm-water species. It is very rare, but occurs rather commonly at Sta. 135.

Range of numbers 0–47 per 1000.
Mean 4.

Like *Globigerina inflata* it occurs chiefly in the eastern Arabian Sea. The following are the mean numbers per station:

Station	119	127	128	132	134	135
Mean	0	0	0	0	6	22

The species was not found at Stas. 119 and 127, and is practically absent from Stas. 128, and 132.

Sta. 134 : It occurs in fair numbers from 90·0 cm. to the bottom of the core, but is absent above this level.

Sta. 135 : Two maxima occur, at 6·0 and 113·0 cm. These correspond to small numbers of *Globigerina bulloides*. Very few tests occur at 33·0 cm. The species is much more abundant in the lower half of the core.

Globigerinella digitata (Brady).

This species also occurs mainly in tropical waters. It is rare in the Arabian Sea.

Range of numbers 0–22 per 1000.
Mean 2.

The species was not found at Stas. 119 and 134, and is rare at Stas. 127 and 128. It is slightly commoner at Sta. 132.

Sta. 135 : The species is fairly common here. The highest numbers occur at 33·0 cm. It was not found at 61·0 cm.

Orbulina universa d'Orbigny.

Although widely distributed the species is most abundant in tropical waters. Fragments of the test of this species are recognizable in all but one sample from Sta. 134 ; whole tests are often wanting. It is most abundant at Sta. 135.

Range of numbers 0–49 per 1000.
Mean 14.

O. universa seems to be generally distributed over the Arabian Sea, occurring rather more frequently in shallow water (Stas. 119, 135). Mean numbers per station follow :

Station	119	127	128	132	134	135
Mean	18	14	11	14	7	23

Sta. 119 : There is a sharp fall in numbers at 33·0 cm., in the mud section of this core. The numbers rise again in the lower layer of Globigerina ooze.

Sta. 127 : A single maximum occurs at 25·0 cm. corresponding to a decrease in *Globigerina bulloides*. The numbers at all levels tend to vary inversely with those of *Globigerina bulloides*.

Sta. 128 : The species is more abundant in the upper half of the core. Increased numbers occur at 22·0 and 65·0 cm.

Sta. 132 : Greatly increased numbers occur at 45·0 cm. There is a slight rise at 108·0 cm.

Sta. 134 : The species is rare in the upper 60·0 cm. of the core. Considerably more specimens occur in the lower half, being most abundant from about 90·0 cm. to the bottom of the core.

Sta. 135 : Maximum numbers occur at 33·0 and 86·0 cm. corresponding to high numbers of *Globigerina bulloides*.

Pulleniatina obliquiloculata (Parker and Jones).

This warm-water species is frequently abundant ; it is present in all the samples examined.

Range of numbers 13–145 per 1000.
Mean 56.

The tests are very common at all stations, as the following means show :

Station	119	127	128	132	134	135
Mean	62	55	65	41	48	66

Sta. 119 : The species is very common except in the mud section, *i.e.*, at 33·0 and 47·5 cm. It is most abundant in the upper Globigerina ooze layer.

Sta. 127 : Numbers are rather constant throughout most of the core, but rise to a maximum at 86·5 cm.

Sta. 128 : Larger numbers are found at 5·0, 46·0 and 110·5 cm., at all of which levels *Globigerina bulloides* is rather less common than at adjacent levels. Comparatively few specimens occur at 130·5 cm. Apart from the increased numbers at 46·0 and 110·5 cm., there is a fairly steady decrease in numbers from 5·0 cm. to the bottom of the core.

Sta. 132 : The species is most common in the centre of the core between 26·5 and 63·0 cm.

Sta. 134 : Larger numbers occur at 29·0 and 107·5 cm. The first of these corresponds to low numbers of *Globigerina bulloides*. The second is 17·5 cm. lower than the second *Gl. bulloides* minimum. Small numbers correspond to the *Gl. bulloides* maximum at 5·0 cm.

Sta. 135 : The fluctuation in numbers is opposite to that of *Globigerina bulloides*, but there is no rise corresponding to the fall in numbers of this species at 61·0 cm.

Sphæroidinella dehiscens (Parker and Jones).

Whole tests are uncommon, but fragments occur in most of the samples examined. It is most common at Sta. 134.

Range of numbers 0–46 per 1000.
Mean 9.

The species tends to be more frequent in deep-water samples. This is doubtless due to the greater resistance of the massive test of this species to solution compared with more delicate forms. The following are the average numbers at each station :

Station	119	127	128	132	134	135
Depth (m.)	1204	4091	4060	4082	4234	2727
Mean	3	11	10	5	28	2

It is thus commonest in the core from the deepest locality.

Sta. 119 : Only a few specimens occur here, none of them in the mud section of the core.

Sta. 127 : Few specimens occur in the upper part of the core. The species is quite frequent at 51·0 and 86·5 cm. The highest numbers occur at the latter depth.

Sta. 128 : The distribution is the reverse of that at the previous station. Most specimens occur in the top 5·0 cm. The number of specimens varies inversely with the number of *Globigerina bulloides*. There is a sharp drop in numbers at 65·0 and 130·5 cm.

Sta. 132 : The species is rather uncommon. Slight increases in the numbers present occur at 63·0 and 91·0 cm.

Sta. 134 : Maximum numbers occur at the surface and at 90·0 cm., but there is no increase or decrease comparable to the drop in numbers of *Globigerina bulloides* at 29·0 cm.

Sta. 135 : The species is rare and is quite absent at 61·0 ems.

Globorotalia canariensis (d'Orbigny).

This species was only found in a few samples. It is fairly common at two levels from Sta. 135, but elsewhere it is rare.

Range of number 0–17 per 1000.
Mean 1.

The average number per 1000 at each station is less than 1 except at Sta. 135, where the mean rises to 6, due to much larger numbers of specimens at 6·0 and 86·0 cm.

Globorotalia crassa (d'Orbigny).

This species occurred in about three-fourths of the samples, and is most frequent at Sta. 128. It is one of the few cold-water forms present in the deposits.

Range of numbers 0–78 per 1000.
Mean 15.

Gl. crassa appears to be commoner in deposits west of the Carlsberg Ridge, as the following figures indicate (Sta. 132 is on the Ridge) :

Station	119	127	128	132	134	135
Mean	13	14	26	17	7	2

Sta. 119 : This species is entirely absent at 33·0–47·5 cm. At higher and lower horizons the numbers are approximately equal.

Sta. 127 : A distinct maximum concentration of the species occurs at 25·0 cm., where fewer *Globigerina bulloides* occur. It is very rare in the top 4·0 cm. of this core.

Sta. 128 : The largest numbers occur at 46·0 and 130·5 cm., and there are marked minima at 22·0 and 110·0 cm. The maximum at 46·0 cm. coincides with the middle *Globigerina bulloides* minimum.

Sta. 132 : The species is absent in the top 6·0 cm., where *Globigerina bulloides* is abundant. In the middle of the core it is fairly common, especially at 45·0 cm., where *Gl. bulloides* is at its minimum, and at the bottom the number falls again and that of *Gl. bulloides* rises.

Sta. 134 : *Gl. crassa* is absent from the top and bottom of the core, but present in the centre part, being most abundant at 29·0 cm., where the number of *Globigerina bulloides* is smallest.

Sta. 135 : *Gl. crassa* is uncommon in this core, occurring at two levels only, in both of which *Globigerina bulloides* is common.

Globorotalia menardii (d'Orbigny).

This is the commonest species of *Globorotalia* and is next in abundance to *Globigerina bulloides*. It is present in all the samples examined, usually in considerable numbers. It is essentially a tropical species.

Range of numbers 18–450 per 1000.
Mean 185.

The mean figures for each station indicate that the species is commoner in the deposits from deep water. This is almost certainly due to the greater resistance of these large tests to decay and solution. The mean numbers are given below :

Station	119	127	128	132	134	135
Mean	82	181	264	137	301	108

There is a very marked inverse fluctuation of this species compared with *Globigerina bulloides*.

Sta. 119 : There is a marked fall in numbers at 33·0 cm. Above and below this level the species is very common.

Sta. 127 : A marked fall in numbers occurs at 51·0 cm.

Sta. 128 : No less than four minima occur at 0, 22·0, 87·0 and 130·5 cm., at all of which levels *Globigerina bulloides* is abundant.

Sta. 132 : There is a decrease in numbers at 6·0 and again at 108·0 cm. It is most abundant at 45·0 cm., where fewest *Globigerina bulloides* occur.

Sta. 134 : In the top and bottom portions of the core this species and *Globigerina bulloides* seem to fluctuate in the same direction, but between 5·0 and 59·5 cm. the fluctuations of the two species are inverse. The number of specimens varies only slightly in the upper half of the core ; it is considerably less in the lower half.

Sta. 135 : *Gl. menardii* is rather less common than at other stations. It is more abundant in the lower half of the core. The fluctuations are opposite to those of *Globigerina bulloides* in the upper half of the core ; but in the lower half the numbers increase continually to the bottom of the core.

Globorotalia truncatulinoides (d'Orbigny).

This is a rather rare species, present in about one half of the samples. It is a tropical form.

Range of numbers 0–39 per 1000.
Mean 5.

The species is commoner in the Somali Basin than on the eastern side of the Arabian Sea, as the following numbers show :—

Station	119	127	128	132	134	135
Mean	9	2	9	4	0	0

Fluctuation in the numbers of the species are generally opposite to those of *Globigerina bulloides*.

Sta. 119: It is entirely absent at 33·0 cm., where *Globigerina bulloides* is abundant.

Sta. 127 : It is very rare. The largest number occur at 51·0 cm.

Sta. 128 : Correlation with the numbers of *Globigerina bulloides* is bad. Fewer specimens occur with the first decrease in *Globigerina bulloides*, an increased number with the second, and the third is doubtful, as *Gl. truncatulinoides* is rare in the lower half of the core. There is a very distinct maximum at 22·0 cm.

Sta. 132 : The species is absent from the two upper levels and rare in the lowest, in all of which *Globigerina bulloides* is abundant.

Stas. 134, 135 : The species is absent from Sta. 134 and practically so from Sta. 135.

Globorotalia tumida (Brady).

This species is next to *Gl. menardii* in order of abundance in the genus, but is much less common. It also is found in tropical waters.

Range of numbers 0–181 per 1000.

Mean 38.

It is generally distributed, being rather more frequent in the western part of the sea.

Station	119	127	128	132	134	135
Mean	25	44	83	7	36	4

Sta. 119 : There is the usual fall in numbers at 33·0 cm.

Sta. 127 : The maximum occurs at 25·0 cm., corresponding to the minimum of *Globigerina bulloides*, and two minima at 51·0 and 96·5 cm., where *Gl. bulloides* is commonest.

Sta. 128 : The numbers fluctuate inversely to those of *Gl. bulloides* in a marked degree. Smaller numbers occur at 22·0, 65·5 and 130·5 cm. as compared with the intervening levels.

Sta. 132 : Decreases in numbers occur at 6·0 and 108·0 cm.

Sta. 134 : Numbers are higher in the centre of the core, falling considerably at the two extremities. The drop in numbers at 107·5 cm. is considerable.

Sta. 135 : Very few specimens occur in this core.

From the foregoing data an idea of the distribution of the tests of pelagic species in the deposits of the Arabian Sea, and some of the species themselves, can be obtained. The apparent distribution of various species is shown in Table III.

TABLE III.—*Range of Distribution of Species.*

	Evenly distributed.	Mainly western part.	Mainly eastern part.	Deep water (> *c.* 4000 m.).	Shallow water (< *c.* 3000 m.).
	Globigerina bulloides *Globigerinoides sacculifera* *Pulleniatina obliquiloculata* *? Globorotalia canariensis*	*Globigerina dubia* *Globigerinoides conglobata* *Orbulina universa* *Globorotalia crassa* *Gl. truncatuloides* *Gl. tumida*	*Globogerina inflata* *Globigerinella æquilateralis* *Gl. digitata*	*Sphæroidinella dehiscens* *Globorotalia menardii*	*Globigerinoides rubra* (*Pulleniatina obliquiloculata*) (*Orbulina universa*)
Total	4	6	3	2	1 (3)

The first three columns in all probability indicate real geographic distribution of species. The fourth and fifth columns probably show the distribution of dead tests only, and are probably due to differential destruction of the tests of the species. The one species found chiefly in shallow water, *Globigerinoides rubra*, has a small delicate test, unlikely to survive a long slow descent through the water without damage. The specimens of *Gl. rubra* identified were always complete tests, no fragments were found. Once broken it is probable that dissolution is rapid. Consequently, tests are to be expected only in comparatively shallow water. *Orbulina universa* and *Pulleniatina obliquiloculata* also show a tendency to collect in shallow water. This again is to be correlated with a rather delicate test. In *Orbulina universa* the spherical test is very thin, with large perforations, and is easily crushed, as is evident from the few whole tests, but many fragments, that are present. The smooth polished test of *Pulleniatina obliquiloculata* appears solid enough, but many of the specimens exhibit considerable erosion of the surface, and are very soft and crumble when touched. Evidently these two species do not survive a long passage to the bottom, but are broken up and probably dissolved on the way down.

The two " deep-water " species, *Sphæroidinella dehiscens* and *Globortalia menardii* exhibit the opposite characteristics. In both the test is massive and not easily broken. Consequently the tests tend to accumulate on the bottom and in deep water, owing to the solution of the more delicate forms, comprise a greater proportion of the deposit than of the living population of pelagic Foraminifera.

The proportions of each species in the deposit are thus, in part, at least, determined by selective destruction and hence differ from those of the living individuals occurring at the surface of the sea. Because of this the proportions found in one core are not strictly comparable with those found in another if the depths of deposition differ substantially. The depths from which four of the present cores come are within a range of 174 m. and thus are comparable. The other two, from Stas. 119 and 135, are from much shallower water, and so might be expected to contain more of the more delicate forms, though movement of the deposit by currents probably destroys considerable numbers.

From the stratigraphical standpoint the most important changes are those at successive levels in the deposit. Depth and selective destruction do not matter here, as the materials to be compared come from the same core and are only separated by a few centimetres vertically. Accordinlgy more reliance can be put upon such comparisons than upon horizontal ones. The main assumption made is that the relative rates of solution of the tests have been the same since the lowest part of the core was deposited.

Further to illustrate the difficulty of correlating the cores Table IV may be cited. This shows the mean numbers of each species at successive levels for all six cores, the samples being grouped over short vertical depth-ranges. It has already been seen that individual cores show stratification in the numbers of individual species. In this table, however, these variations are less apparent, being smoothed out in averaging the samples. Only two *Globigerina bulloides* maxima occur as against three if the cores are taken separately. The explanation that there is no real stratification in the cores, the apparent stratification being due to sampling errors, is eliminated by the existence of visible signs of stratification, as at Sta. 119. The true explanation is probably that the rate of deposition varies with each region and deposit, so that comparable horizons are not quite at the same depths below the deposit surface. This is more likely, as the rate must be influenced by many factors, such as proximity to land and consequent abundance or lack of inorganic material,

abundance of remains of organisms, depth, solution, currents and no doubt other factors. Furthermore the tops of the cores do not represent the deposit surface, as variable amounts are lost from each during collection. These factors are apparently sufficient to eliminate evidence of the third peak of *Gl. bulloides*, which is less pronounced than the others. Hence in considering the stratification and variations in numbers of Foraminifera, each core must be treated separately.

Table IV.

Depth in core. (cm.)	*Globigerina bulloides.*	*Globigerina dubia.*	*Globigerina inflata.*	*Globigerinoides conglobata.*	*Globigerinoides rubra.*	*Globigerinoides sacculifera.*	*Globigerinella aequilateralis.*	*Globigerinella digitata.*	*Orbulina universa.*	*Pulleniatina obliquiloculata.*	*Sphæroidinella dehiscens.*	*Globorotalia canariensis.*	*Globorotalia crassa.*	*Globorotalia menardii.*	*Globorotalia truncatulinoides.*	*Globorotalia tumida.*	Benthic spp.
0	536	68	15	26	25	23	2	1	11	53	14	0	6	152	4	37	29
4–6	485	69	14	23	16	26	2	3	13	69	9	3	8	193	2	52	14
22–33	482	86	19	15	17	18	1	5	17	62	8	2	20	206	4	35	8
51–65	515	88	16	12	24	12	5	1	21	59	10	2	15	175	6	24	19
90–96·5	481	73	33	5	3	9	5	1	10	37	14	1	13	246	3	48	20
107·5–113	469	66	51	9	17	12	15	2	11	71	8	0	5	201	1	38	25

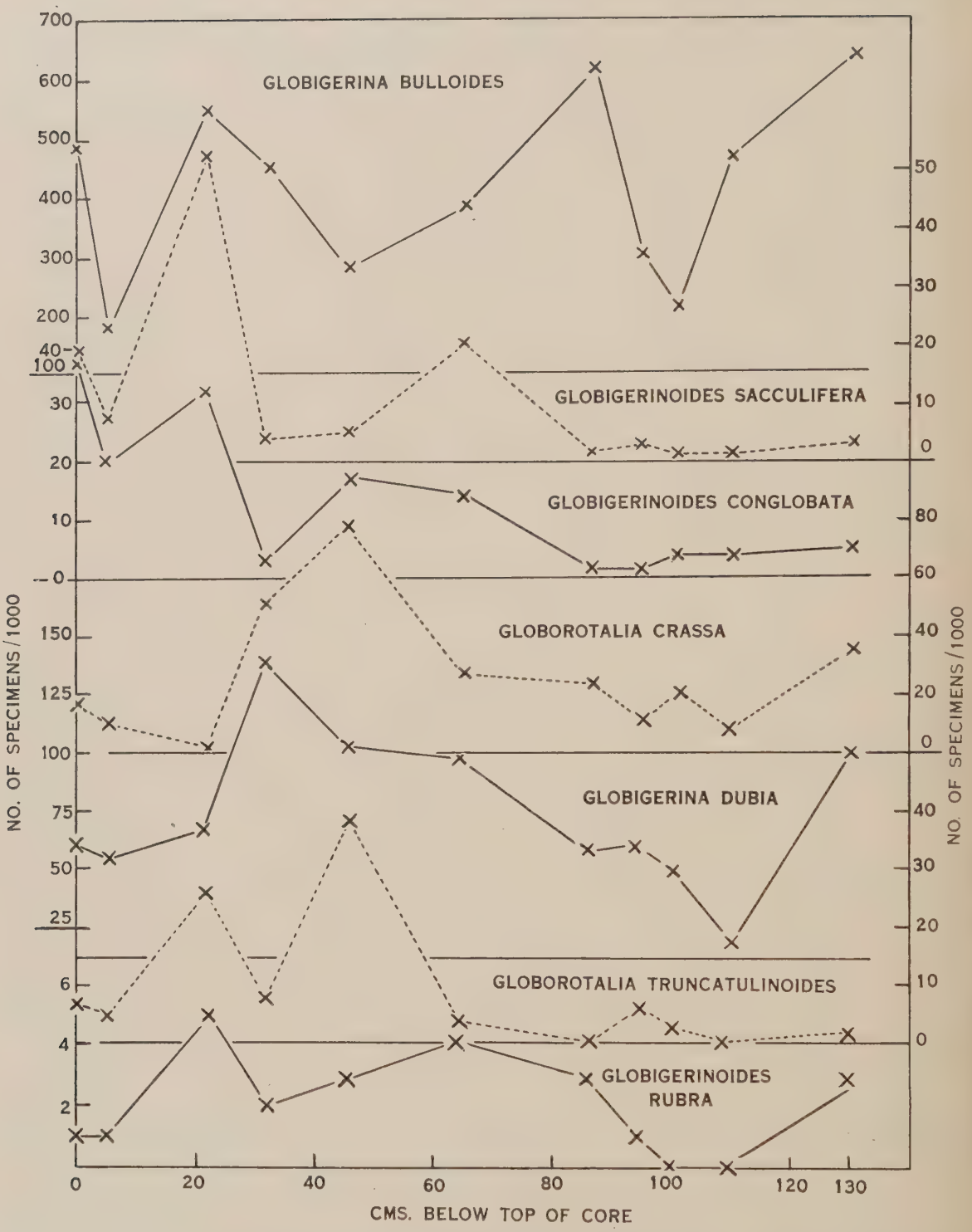
The foregoing statements of the fluctuations of the several species may now be summarized. It is seen that a few species agree with *Globigerina bulloides* in some parts of the cores, but not at all levels. Many more species fluctuate in the opposite direction while a number may vary irregularly.

In the following graphs (Text-figs. 1 and 2) thirteen of the species found at Sta. 128 have been plotted. The other three species are very rare. It is seen that *Gl. bulloides* stands practically alone. *Globigerinoides conglobata*, *Gl. sacculifera* and *Gl. rubra* (Text-fig. 1) agree fairly closely with it in their fluctuations, but their maxima tend to occur at slightly different levels to those of *Globigerina bulloides*. The initial fall from 0 to 5·0 cm. is not shown by *Globigerinoides rubra* ; this species shows the final rise at the bottom of the core as does *Globigerina bulloides*. The other two species of *Globigerinoides* do not. The position of the third high value varies. In *Globigerina bulloides* it is at 87·0 cm. In *Globigerinoides sacculifera* and *Gl. rubra* the corresponding peak occurs at 65·0 cm. and in *Gl. conglobata* at 46·0 cm.

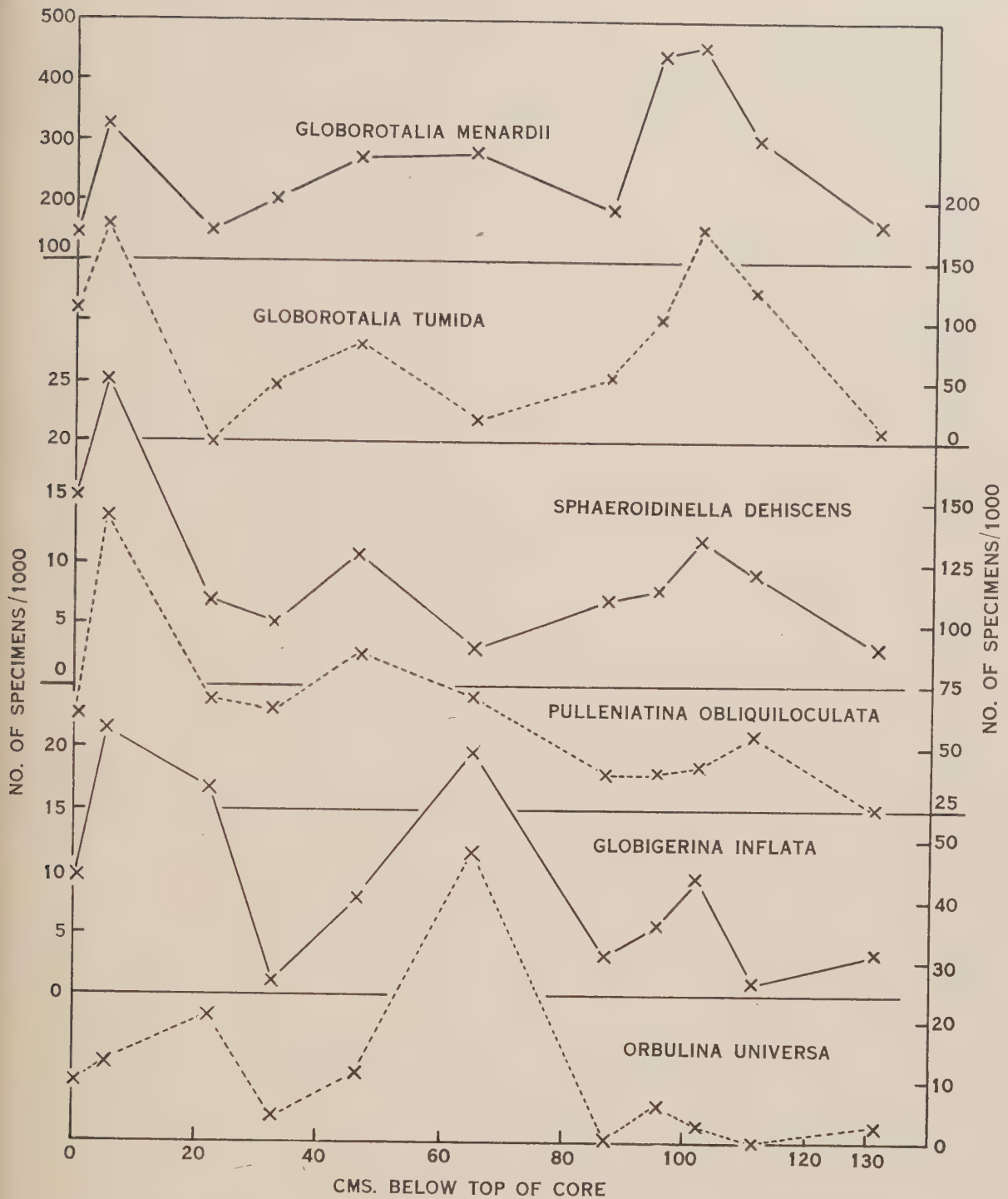
Globigerina dubia shows a well-defined peak at 32·5 cm. and the final rise. This peak probably corresponds to the second of *Gl. bulloides*. *Gl. dubia*, however, does not show a well-defined third peak. Instead the curve descends in a series of steps from the peak at 32·5 cm. to a minimum at 110·5 cm., and then rises to a final high value at 130·5 cm.

Globorotalia crassa shows a rather similar curve to *Globigerina dubia*, though there is a smaller variation in numbers between 65·0 cm. and the bottom of the core.

The curve for *Globorotalia truncatulinoides* shows three maxima, of which the first agrees in position with the second of *Globigerina bulloides*. The second is much nearer the first than in this latter species. The third also is at a higher level than in *Gl. bulloides*. This species, in company with *Globigerinoides conglobata* and *Gl. sacculifera* shows only minor



TEXT-FIG. 1.—Frequency curves for the *Gl. bulloides* group of species. (The vertical scales to the right of the diagram refer to the curves drawn in broken lines; those on the left to the curves in plain line.)



TEXT-FIG. 2.—Frequency curves for the *Globorotalia menardii* group of species. (The three vertical scales to the right of the diagram refer to the curves drawn in broken lines; those on the left to the curves in plain line.)

fluctuations below 95·0 cm. There is no peak corresponding to the high value of *Globigerina bulloides* at the surface.

The six species shown in Text-fig. 2 show much greater agreement.

These species show maxima where the foregoing showed minima. Each of the species, *Globorotalia menardii*, *Gl. tumida*, *Sphæroidinella dehiscens*, *Orbulina universa*, *Pulleniatina obliquiloculata* and *Globigerina inflata* shows three maxima. Except for a slight divergence in the case of *Orbulina*, these maxima are at practically the same level for all species.

According to Philippi (1910, p. 568) all the species shown in the two graphs are found mainly in equatorial waters. The three exceptions are *Globigerina bulloides*, *Gl. inflata* and *Globorotalia crassa*. On this grouping these three would be expected to show similar fluctuation curves. Actually they do not agree very closely. The curves of *Globigerina bulloides* and *Globorotalia crassa* bear some resemblance to one another, but that of *Globigerina inflata* is quite different. This curve agrees with those of essentially tropical species. *Gl. inflata* is as widely distributed and penetrates as far into high latitudes as *Gl. bulloides*. Like the latter species it is said to be essentially a cold-water form. It has already been stated that it is not very common in the Arabian Sea, though *Gl. bulloides* is often abundant. This suggests that its fluctuations are not entirely due to temperature conditions. The presence of large numbers of *Gl. bulloides* may restrict its numbers, perhaps by reducing the available food supply. How far the interrelations of all the species affect the numbers of each it is impossible to say, but there is doubtless some measure of competition between the species.

The majority of pelagic species have a very wide range of distribution north and south of the equator. Thus *Globigerina dubia*, said by Philippi to be a warm-water species, is recorded by Brady (1884, p. 595) as occurring as far north as 56° N. lat., and as far south as 46° S. lat. It is thus difficult, if not impossible, to draw a hard and fast line between warm- and cold-water species. A species may penetrate much farther north in the Atlantic Ocean than, say, in the Pacific, depending upon the temperature of the water mass in which it is drifting. Moreover, many species must find their optimum conditions somewhere between the two extremes of heat and cold. It is possible that those species giving intermediate curves, *e.g.*, *Orbulina universa* and *Globorotalia crassa*, are such.

The above graphs (Text-figs. 1 and 2) illustrate all the common species at one station only. Very similar fluctuations occur at the other stations from which the same types of curve can be drawn.

IV. THE BENTHIC FORAMINIFERA.

Benthic Foraminifera are not very abundant in the deposits except in a few surface samples, notably from Stas. 119 and 134. They occur at all levels examined. The variations in numbers per 1000 tests are shown below :

Range 3–73.
Mean 17.

The actual numbers per 1000 tests at each station and level examined are shown in the last column of Table I. They represent all species present, whether identified or not. The commoner species alone have been identified and appear below under their respective stations and levels.

Station 119.

0 cm.: *Rhabdammina abyssorum*, *Rh. discreta*, *Rh. linearis*, *Marsipella elongata*, *Tholosina bulla*, *Hyperammina friabilis*, *Dendrophrya ramosa*, *Reophax nodulosus*, *Ammodiscus incertus*, *Ammodiscoides turbinatus*, *Ammolagena clavata*, *Cyclammina compressa*, *Verneulina propinqua*, *Triloculina* sp., *Pyrgo depressa*, *P. murrhina*, *Lenticulina subalata*, *Dentalina filiformis*, *Nonion umbilicatulum* and *Bolivinita quadrilatera*.

4·5 cm.: *Reophax* sp., *Textularia ? concava*, *T. gramen*, *Gaudryina robusta*, *Clavulina parisiensis*, *Quinqueloculina* sp., *Sigmoilina schlumbergeri*, *Triloculina trigonula*, *Pyrgo depressa*, *Robulus* sp., *Dentalina communis*, *Saracenaria italica*, *Lagena marginata*, *Nonion umbilicatulum*, *Bulimina elegans*, *B. ovata*, *Uvigerina aculeata*, *U. asperula*, *Eponides haidingeri*, *Epistomina elegans*, *Ceratobulimina contraria*, *Cassidulina subglobosa*, *Planulina ariminensis* and *Cibicides lobatulus*.

10·5 cm.: *Textularia* sp., *Pyrgo murrhina*, *Lagena marginata*, *Nonion pompilioides*, *Elphidium crispum*, *E. jenseni*, *Bulimina aculeata*, *Uvigerina pygmæa*, *Rotalia* sp. and *Cassidulina subglobosa*.

33·0–33·5 cm.: *Pyrgo depressa*, *Ophthalmidium inconstans*, *Robulus* sp., *Cassidulina subglobosa* and *Chilostomella ovoidea*.

47·5–48·0 cm.: *Ophthalmidium inconstans*, *Lagena marginata*, *Uvigerina asperula* and *Cassidulina subglobosa*.

58·5–60·0 cm.: *Pyrgo murrhina*, *Robulus* sp., *Lagena marginata*, *Nonion umbilicatulum*, *Bulimina aculeata*, *Uvigerina asperula*, *U. pygmæa*, *Ceratobulimina contraria* and *Cassidulina subglobosa*.

65·0 cm.: *Gaudryina baccata*, *G. robusta*, *Clavulina communis*, *Quinqueloculina* sp., *Massilina arenaria*, *Sigmoilina schlumbergeri*, *Pyrgo depressa*, *P. lucernula*, *Robulus* sp., *Nodosaria* sp., *Nonion umbilicatulum*, *Uvigerina aculeata*, *U. asperula*, *Eponides haidingeri*, *Epistomina elegans*, *Ceratobulimina contraria* and *Cibicides lobatulus*.

Station 127.

0 cm.: No benthic species.

4·0–4·5 cm.: *Reophax nodulosus*, *Lagena longispina*, *Virgulina subsquamosa*, *Cassidulina subglobosa* and *Planulina wuellerstorfi*.

25·0–26·5 cm.: *Verneulina bradyi*, *Lagena marginata* and *Virgulina subsquamosa*.

51·0–52·5 cm.: *Nonion pompilioides*.

86·5–88·0 cm.: *Pyrgo murrhina*, *Nonion pompilioides* and *Planulina wuellerstorfi*.

96·5–98·5 cm.: *Robulus* sp., *Lagena marginata* and *Cassidulina subglobosa*.

Station 128.

0 cm.: *Verneulina bradyi* and *Rotalia* sp.

5·0–5·05 cm.: *Pyrgo depressa*, *Robulus? gibbus*, *Rotalia* sp. and *Laticarinina pauperata*.

22·0–23·5 cm.: *Lagena marginata*, *Uvigerina asperula* and *Cassidulina subglobosa*.

32·5–34·0 cm.: *Pyrgo murrhina*, *Robulus* sp., *Lagena marginata*, *Lagena* sp., *Virgulina subsquamosa*, *Uvigerina asperula*, *U. pygmæa*, *Cassidulina subglobosa* and *Chilostomella ovoidea*.

46·0–46·5 cm.: *Verneulina bradyi, Gaudryina baccata, Pyrgo murrhina, Nonion umbilicatulum, Uvigerina pygmæa* and *Rotalia* sp.

65·5–67·0 cm.: *Pyrgo murrhina* and *Uvigerina pygmæa.*

87·0–89·0 cm.: *Pyrgo murrhina, Dentalina* sp., *Nonion umbilicatulum, Bulimina ovata* and *Chilostomella ovoidea.*

95·0–96·5 cm.: *Gaudryina baccata, Pyrgo murrhina, Uvigerina asperula* and *Cassidulina subglobosa.*

101·5 cm.: *Pyrgo murrhina, Lagena* sp., *Nonion umbilicatulum, Uvigerina pygmæa, Rotalia* sp. and *Cassidulina subglobosa.*

110·5–112·0 cm.: *Pyrgo murrhina, Lagena marginata, Nonion pompilioides, Uvigerina asperula* and *Cassidulina subglobosa.*

130·5–132·0 cm.: No benthic species.

Station 132.

0 cm.: *Verneulina bradyi, Pyrgo murrhina, Lagena seminiformis* and *Nonion pompilioides.*

6·0–8·0 cm.: *Pyrgo murrhina* and *Chilostomella ovoidea.*

26·5–28·0 cm.: *Pyrgo murrhina, Nonion pompilioides, Virgulina subsquamosa, Uvigerina asperula, Chilostomella ovoidea, Planulina ariminensis* and *P. wuellerstorfi.*

45·0–47·0 cm.: *Planulina wuellerstorfi.*

63·0–64·5 cm.: *Pyrgo murrhina.*

91·0 cm.: *Pyrgo murrhina.*

108·0–109·5 cm.: *Pyrgo murrhina, Nonion pompilioides* and *Rotalia* sp.

Station 134.

0 cm.: *Virgulina subsquamosa.*

5·0–6·0 cm.: *Reophax* sp., *Haplophragmoides ? latidorsatus, Nonion pompilioides, N. umbilicatulum* and *Rotalia* sp.

29·0–30·5 cm.: *Pyrgo murrhina, Nonion pompilioides* and *N. umbilicatulum.*

59·5–61·0 cm.: *Lagena marginata, Glandulina rotundata, Nonion pompilioides, Uvigerina pygmæa, Rotalia* sp., *Cassidulina subglobosa, Planulina ariminensis* and *P. wuellerstorfi.*

90·0 cm.: *Textularia agglutinans, T. porrecta, Verneulina bradyi, Triloculina oblonga, Pyrgo murrhina, Nonion pompilioides, Uvigerina asperula, Gyroidina soldanii* and *Planulina wuellerstorfi.*

107·5 cm.: *Textularia agglutinans, Pyrgo depressa, P. murrhina, Lagena alveolata, L. lævis, Nonion pompilioides* and *Uvigerina asperula.*

Station 135.

0 cm.: *Rotalia brœkhiana* and *Planulina wuellerstorfi.*

6·0–7·5 cm.: *Hyperammina friabilis, Glomospira charoides, Clavulina communis, Pyrgo murrhina, Lagena marginata* and *Planulina wuellerstorfi.*

33·5–34·5 cm.: *Gaudryina baccata, Pyrgo murrhina* and *Planulina wuellerstorfi.*

61·0 cm.: *Pyrgo denticulata, P. murrhina, Lagena alveolata, Uvigerina pygmæa* and *Rotalia brœkhiana.*

86·0–88·0 cm.: *Verneulina bradyi*, *Nodosaria* sp., *Lagena marginata*, *Uvigerina pygmæa* and *Laticarinina pauperata*.

113·0 cm.: *Pyrgo murrhina*, *Lagena marginata*, *Planulina wuellerstorfi* and *Laticarinina pauperata*.

All the commoner species are listed above. The number of species present at any one station is small except at Sta. 119, where the number is more than double that at any other station. The numbers at each station are :

Station	119	127	128	132	134	135
No. of species	56	10	19	10	21	14

The presence of this large number of species at Sta. 119 is doubtless due to the shallower habitat. A large number of the species are forms commonly met with near land and in green mud. It is of interest to compare the species met with in the upper and lower layers of Globigerina ooze in this core. Twenty species occur in the surface deposit. At 4·5 cm., still in the Globigerina ooze, twenty-three species occur, but only two of these, *Pyrgo depressa* and *Nonion umbilicatulum*, are common to both levels. In the lower Globigerina ooze, from 60·0 cm. to the bottom of the core, seventeen species occur. This layer has the same two species in common with the surface deposit, but no less than twelve in common with the 4·5 cm. layer, including *Pyrgo depressa* and *Nonion umbilicatulum*.

The intermediate mud-layer, 9·0–60·0 cm., is very poor in species. Only seven were identified ; two, *Ophthalmidium inconstans* and *Chilostomella ovoidea*, occur here only in this core. One, *Cassidulina subglobosa*, occurs also in the 4·5 cm. layer. *Pyrgo depressa* is found at all levels and a species of *Robulus* in the 4·5 cm. sample and the bottom layer as well.

At all other stations there seems to be only a slight correspondence in species at different levels. The possibility that this is due to the very small number of tests present in any one sample must not be excluded. That so many are common to the bottom layer and to the 4·5 cm. layer at Sta. 119 is further evidence of the remarkable similiarity of these two deposits here. From the different species found in the surface deposit, as compared with the 4·5 cm. level, it is evident that there has been a big change in the benthic Foraminiferal fauna during the period of deposition of the top 4·5 cm. of the core. It is remarkable that there is no similar change in the pelagic fauna between these two horizons. Despite the almost complete change of species there is scarcely any change in the total number of benthic Foraminifera present.

The top and bottom layers at Sta. 134 have only one species, *Nonion pompilioides*, in common. At other stations too few species are present for comparison.

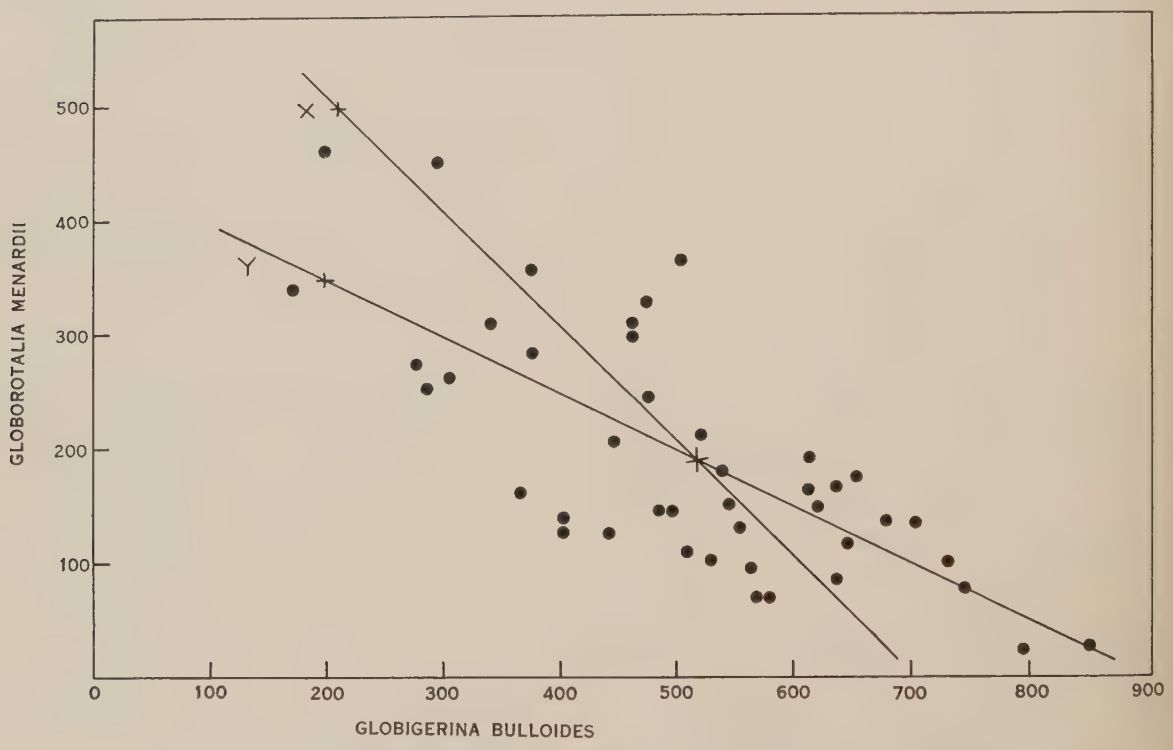
TABLE V.

6 stations.	5 stations.	4 stations.	3 stations.
Pyrgo murrhina	*Verneulina bradyi*	*Virgulina subsquamosa*	*Pyrgo depressa*
	Lagena marginata	*Uvigerina asperula*	*Robulus* sp.
	Nonion pompilioides	*U. pygmæa*	*Nonion umbilicatulum*
		Rotalia sp.	*Planulina ariminensis*
		Cassidulina subglobosa	*Chilostomella ovoidea*
		Planulina wuellerstorfi	*Gaudryina baccata*

There is very little correspondence between the species found at successive peaks in a core, or between those found at the corresponding peaks in different cores. There is, likewise, little similarity between the total Foraminiferal faunas at different stations. Very few species occur at more than two stations. Seventy-one species were identified, of which those listed above (Table V) occurred at more than two stations.

V. THE RATIO BETWEEN *GLOBIGERINA BULLOIDES* AND *GLOBOROTALIA MENARDII*.

In comparing the cores it is sufficient to use only a few of the species as indicators of conditions. *Globigerina bulloides* and *Globorotalia menardii*, as the two commonest, at once suggest themselves. The former species is mainly an inhabitant of cold water, whereas the latter is restricted to tropical and subtropical waters. Moreover, from the counts made there seems to be an inverse relationship between these two species. Statistical treatment shows that this relationship is real. The regression lines for the two species are shown in Text-fig. 3.



TEXT-FIG. 3.—Regression of *Globigerina bulloides* (X) and *Globorotalia menardii* (Y).

The regression coefficients of the two species are :

Globigerina bulloides −1·0.
Globorotalia menardii −0·49 ;

and the standard errors of these coefficients—

Globigerina bulloides 0·151,
Globorotalia menardii 0·072.

The evidence of a population ratio between the two species is thus conclusive.

These species are sufficient to show the trends of climatic conditions in the past. Because of this relationship it is possible to combine the numbers of the two species as a ratio of one to the other. The ratio *Globigerina bulloides*/*Globorotalia menardii* is adopted here. Table VI shows this ratio at all the levels examined in each core. Text-fig. 4 shows these values plotted against the corresponding depths below the tops of the cores. The peaks indicate large numbers of *Globigerina bulloides* relative to *Globorotalia menardii*, and therefore, cold conditions. Low values indicate that *Gl. menardii* is more abundant and that conditions during deposition were warmer.

TABLE VI.

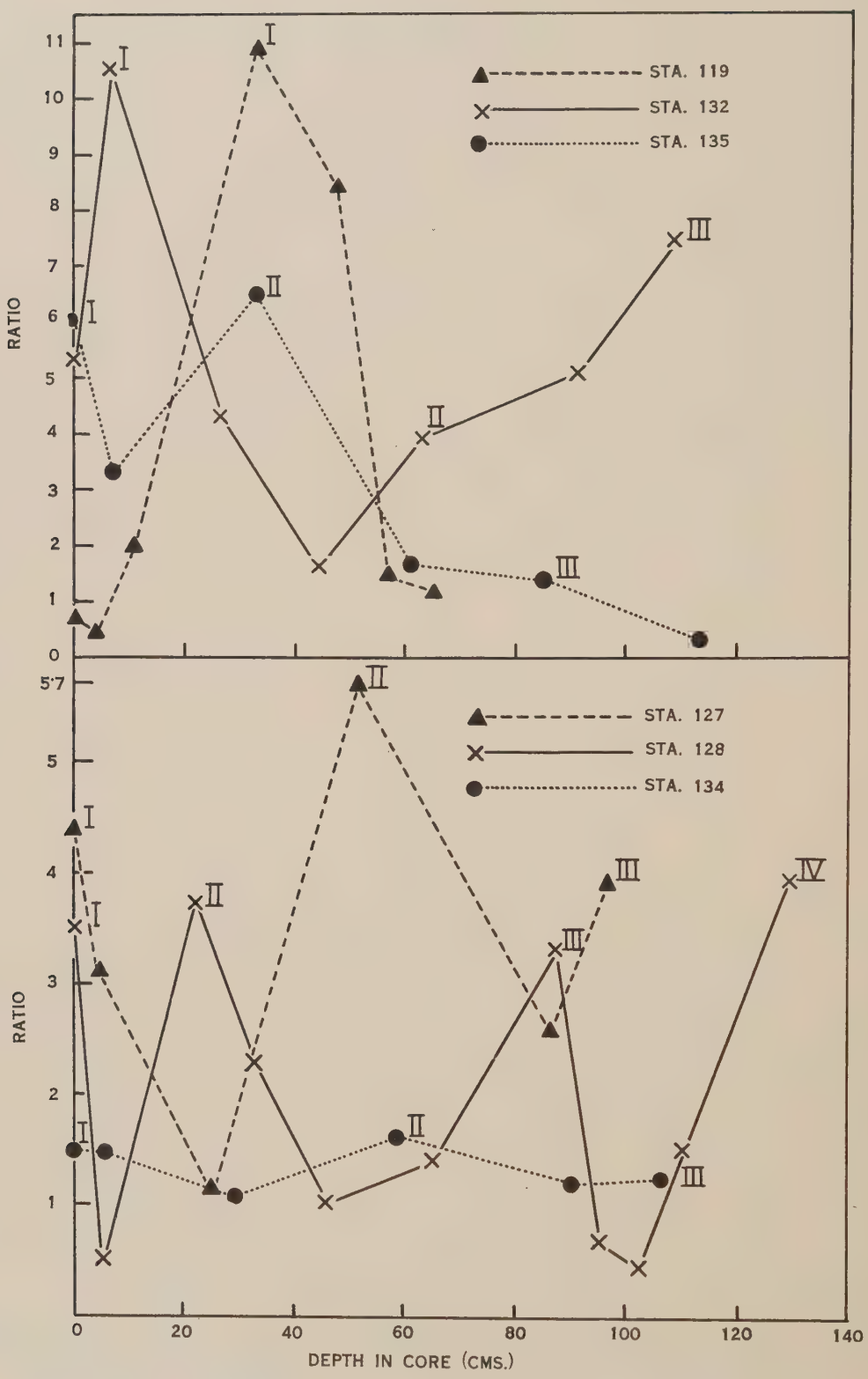
Station.	Cm.	Ratio.	Cm.	Ratio.	Cm.	Ratio.
119	0	3·24	33·0	44·22	65·0	4·88
	4·5	3·15	47·5	3·39	..	..
	10·5	7·88	58·5	6·20	..	..
127	0	4·41	25·0	1·15	86·5	2·54
	4·0	3·13	51·0	5·69	96·5	3·92
128	0	3·52	46·0	1·05	101·5	0·46
	5·0	0·53	65·0	1·39	110·5	1·54
	22·0	3·72	87·0	3·30	130·5	3·94
	32·0	2·28	95·0	0·68	..	..
132	0	5·40	45·0	2·03	108·0	7·58
	6·0	10·20	63·0	4·03	..	..
	26·5	4·38	91·0	5·23	..	..
134	0	1·51	29·0	1·08	90·0	1·19
	5·0	1·47	59·5	1·61	107·5	1·23
135	0	8·10	33·0	8·64	86·0	3·54
	6.0	5·39	61·0	3·69	113·0	2·43

The ratio curves for the different cores are described below.

Sta. 119 : The graph of the *Gl. bulloides*/*Gl. menardii* ratio for this core shows low values in the upper layers and at the bottom of the core. The ratio reaches a very high value within the intermediate mud layer, due to increased numbers of *Globigerina bulloides* and very few *Globorotalia menardii*. This is what would be expected if the mud-layer was deposited under cold conditions. This core is short and the graph shows only the one peak.

Sta. 127 : This core is 96·5 cm. long. Reference to Table I and Text-fig. 4 shows that there are three peaks, at 0, 51·0 and 96·5 cm. The first most probably corresponds to that at Sta. 119. The difference in level is no doubt in part due to loss of the surface of the core. The second peak at 51·0 cm. probably indicates an earlier cold period not represented in the core from Sta. 119. Although that core goes down to a depth of 68·5 cm. the faster rate of deposition in shallow water may explain why the second zone was not reached at this depth. The final rise of the curve at 96·5 cm. indicates a third cold period.

Sta. 128 : This is the longest core obtained. Four cold periods are represented in its length. The first at the top of the core, corresponds to that seen at the surface in the cores from Stas. 119 and 127 ; that at 22·0 cm. corresponds to the second at Sta. 127. Two further peaks at 87·0 and 130·5 cm. appear to indicate still earlier cold periods unrepresented in the preceding cores.



TEXT-FIG. 4.—Ratio *Globigerina bulloides/Globorotalia menardii* plotted against depth.

Sta. 132 : The first peak occurs at 6·0 cm. and corresponds to the first one in the three preceding cores. There is a slight break in the slope of the curve at 63·0 cm., probably indicating the second cold period. A definite peak at 108·0 cm. most probably corresponds to the third cold period. Its depth agrees with this interpretation, as it is reasonably near the position of the third peak at Stas. 127 and 128. Conditions in this region must have changed far less during the second cold period, as there is very little change in the pelagic fauna compared with the changes noticeable at Stas. 127 and 128.

Sta. 134 : Only very small fluctuations are detectable in this core. Without reference to the other cores it might be assumed that the graph of the ratio was a horizontal straight line. By comparison with the others, however, it is seen that the ratio rises slightly at depths corresponding to peaks in the graphs of the other cores. Slight increases in the ratio at 0 and 59·5 cm. appear to correspond to the first and second peaks of the other cores. A third rise is very doubtful. The ratio increases very slightly from 90·0 to 107·5 cm., so there may be a third peak below this depth in the deposit at this station, but the Bigelow tube penetrated no deeper. The top part of the core is evidently lost.

Sta. 135 : This core shows the first two peaks distinctly. The third is indicated by a break in the slope of the curve at 86·0 cm. The upper few centimetres of ooze appear to have been lost.

The six cores thus show up to a maximum of four zones in which the ratio is high. The position of these zones in the cores is summarised below, Table VII, together with the total lengths of the cores.

TABLE VII.

Station.	Length (cm.).	No. of zones.	Depths of zones (cm.).			
			1st.	2nd.	3rd.	4th.
119	68·5	1	33·0	..	..	..
127	96·5	3	0	51·0	96·5	..
128	132·0	4	0	22·0	87·0	130·5
132	116·0	3	6·0	63·0	108·0	..
134	118·0	3	0	59·5	107·5	..
135	120·5	3	0	33·0	86·0	..

It is convenient to begin the discussion with a consideration of the core from Sta. 119. As already stated (p. 162), this core has a stratum of calcareous mud enclosed between two strata of Globigerina ooze. It is apparent that conditions must have been very different during the period of deposition of this mud from what they were at an earlier period, or are at the present time. This middle stratum contains a considerable amount of clayey material and is evidently of terrigenous origin. There can be little doubt that this layer was deposited under conditions similar to those described by Philippi (1910) and Wüst (1933). That is to say, it is of glacial age. Being from a tropical locality it is not composed of glacial material, but is a water-borne detrital sediment. Its deposition far from land is due to the high precipitation during the pluvial period in these regions and the consequent strong flow of sediment-laden water into the sea. The scarcity of the warm-water species, *Globorotalia menardii*, supports this supposition.

This core forms a basis for correlating the others as the time of deposition of the mud zone can be determined approximately.

ratio indicate relatively large numbers of *Globigerina bulloides* and consequently cold conditions, probably glacial. No less than four such " cold zones " are present in the longest core obtained. The intermediate zones of the cores with relatively more *Globorotalia menardii*, and, therefore, a smaller ratio, represent warmer interglacial periods.

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